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ABSTRACT

Intended primarily but not solely for use at the postsecondary level, this curriculum guide contains five units of materials on energy efficiency that were designed to be incorporated into an existing program in building construction. The following topics are examined: conservation measures (residential energy use and methods for reducing residential energy costs); construction techniques for energy efficient buildings (techniques for planning and constructing an energy efficient building, taking advantage of local topography, climate considerations, and complying with standard construction practices and state/local building codes); insulation materials and R-values; construction materials and their application (selection of window, door, and framing materials); and passive and active solar energy. Covered in each lesson are unit rationale, necessary advanced preparations, anticipated instructional time, guidelines for implementing the unit, unit activities, and unit references. (MN)

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ENERGY EFFICIENCY FOR BUILDING CONSTRUCTION TECHNOLOGY

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PREFACE

This curriculum guide was produced by the Nebraska Energy Office in a cooperative effort with the Nebraska State Department of Education. These organizations are dedicated to the development of quality educational materials that promote wise energy management.

The following individuals assisted in the production of these materials:

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These materials will be piloted during the 1981-82 school year, revised, and subsequently made available statewide in the 1982-83 academic year.

All inquiries, suggestions, or comments regarding this curriculum guide should be directed to:

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INTRODUCTION

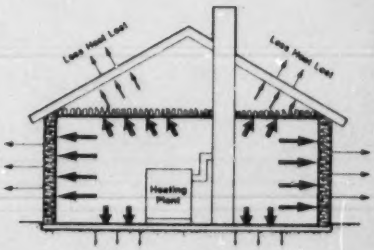
This curriculum guide contains five units that were designed to be incorporated into an existing program of Building Construction Technology. The material is primarily intended for use at the post-secondary level. A well-equipped secondary instructor, however, will also find the information useful.

The five units may be taught independently or collectively depending on the needs of the instructor at any single institution. The content of these units has been written and organized into an outline format. Each unit outline, in order to facilitate articulation between units, consists of the following sections: rationale, advanced preparation, anticipated instructional time, unit guide, activities, and references.

The degree of coverage depth, instructional time and evaluation of student performance are left at the discretion of the individual instructor. Suggested activities are included but are by no means comprehensive. Instructors should feel free to add, delete or substitute activities, references, and audiovisual materials. The Nebraska Energy Office encourages innovation to best suit the needs of the individual instructor.

The overall objective of this curriculum guide is to provide the Building Construction instructors in Nebraska with a format to achieve continuity in their approach to teaching energy efficiency for Building Construction Technology.

Less heat escaping means less heat and less fuel needed to stay comfortable inside



COURSE RATIONALE

This course is designed to promote the understanding and application of some important energy conservation practices in Building Construction. A thorough understanding of the principles discussed in the units to follow, will allow the student to maximize the potential energy efficiency of Building Construction techniques.

The principal energy efficient Building Construction practices are discussed in the following units:

1. Conservation Measures - Presents an overview of residential energy use and methods for reducing residential energy costs.

2. Construction Techniques for Energy Efficient Buildings - Deals with techniques in planning and constructing an energy efficient building, taking advantage of local topography, climate considerations, and complying with standard construction practices and state/local building codes.

3. Insulation Materials and R-Values - Provides information concerning the effectiveness of insulation relative to its resistance to heat flow (R-Value), composition, and thickness.

4. Construction Materials and Application - Provides information concerning the selection and application of window, door, and framing materials to improve the efficiency of energy use in new residential buildings.

5. Solar: Passive and Active - Deals with the two basic types of solar energy (Passive and Active) and how they might be incorporated into the construction or retrofit of a building.

Although this guide is designed to promote thorough Building and Construction energy conservation principles, conservation alone will not solve our present or future energy problems. Continued conservation, sound energy management, and technological improvements will, however, buy our nation precious time until self-sufficiency based on alternate energy sources becomes feasible.

UNIT I

CONSERVATION MEASURES

RATIONALE

Most of our residential energy, 70 percent, is used to heat and cool our homes. An additional 20 percent goes for heating water, the second largest home energy user and expense. The remaining 10 percent goes into lighting, cooking, and running small appliances.

We can cut our energy use and help control living costs by making our homes energy efficient, even if we have to spend money to do it. The money we spend now, however, can help hold down energy costs for many years to come.

This unit is designed to explain various residential energy saving tips in relation to Building Construction practices.

ADVANCED PREPARATION

It is recommended that the publications "Tips for Energy Savers" and the "Nebraska Energy Saving Manual" be obtained from the Nebraska Energy Office prior to beginning this Unit.

ANTICIPATED INSTRUCTIONAL TIME

The information contained in this Unit should be incorporated within an existing curriculum in Building Construction Technology.

UNIT GUIDE

1. ENERGY CONSERVATION CONSIDERATIONS

   It is the responsibility of the professional builder, because of increasing energy costs, to maximize the efficiency of all residential structures. Factors to consider when designing or retrofitting a structure include:

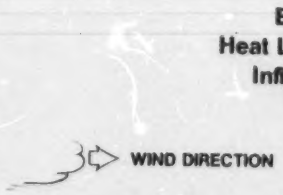
   A. The type of fuel used to heat the structure (and its cost).
      1. Natural gas
      2. Electricity
      3. Fuel oil
      4. Woodstoves
      5. Active and/or passive solar

   B. Consider the environmental and constructional problems associated with a particular type of fuel and its availability.

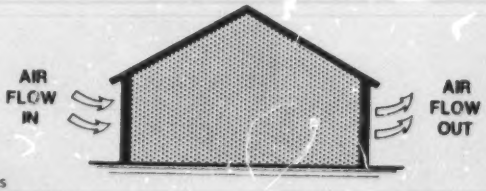
   C. Cost to benefit ratio of remodeling a structure for energy efficiency.

D. Insulation - a fundamental necessity
   1. R-values
   2. Building standards (Use the most STRINGENT)
      a. Federal code (for all FHA and HUD homes)
      b. State (where no local code exists)
      c. County
      d. Local
   3. Types
      a. Batt
      b. Foam
      c. Poured-in
      d. Rigid

E. Doors and Windows
   1. Repairs/retrofits
   2. Replacement for energy efficiency
   3. Putty, caulking, and painting
   4. Window types
      a. single pane
      b. thermal pane
      c. triple pane
      d. awning
      e. casement
      f. picture windows
      g. sliding windows
   5. Door types
      a. metal clad
      b. solid core
      c. panels
      d. sliding doors



F. Infiltration
   1. Doors
   2. Windows
   3. Siding
   4. Foundation
   5. Ceilings



G. Fireplaces
   1. Damper, glass doors
   2. Venting (inside to outside)
      a. Proper damping
      b. Heat exchanger
      c. Air - heating grate

H. Landscaping
   1. Berm wall
   2. Tree placement
      a. Deciduous trees - place on the South and East sides.
      b. Coniferous trees - place on the North and West sides.

I. Ducts
   1. Insulation
   2. Vapor barriers

J. Woodstoves
   1. Energy efficiency ratings
   2. Air-tight construction
   3. Insulate the stove area with asbestos
   4. Set stove away from the wall according to manufacturer's specifications.
   5. Check flues periodically for creosote buildup

K. When remodeling walls etc.
   1. Use 15# felt on the exterior
   2. Use polystyrene sheets or their equivalent on the interior.

(NOTE: These materials should be used in addition to insulation already in place)

UNIT ACTIVITIES

1. Using the checklist on the following page, visit an actual construction site and determine the degree to which energy efficient techniques are being implemented.

2. Using the "Nebraska Energy Saving Manual", research and perform a building energy audit on your home, school, or local building.

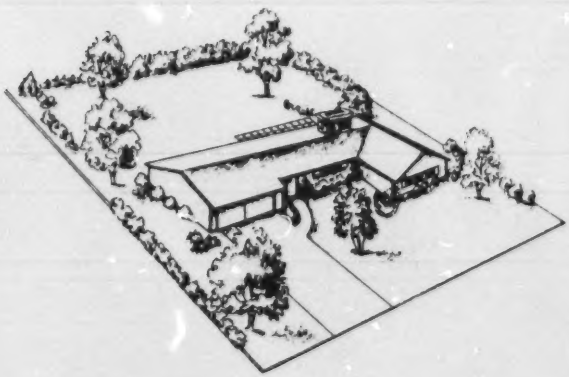


FIGURE ONE

Energy-Saving Checklist for Home Builders, Buyers, and Owners

This checklist contains many items that you should consider when building, renovating, or improving the energy efficiency of your home.

Building Shell	Yes	No	NA
1. Are storm windows and storm doors installed?			
2. Are window panes and frames properly caulked? Do windows open for natural ventilation?			
3. Are exterior doors weather-stripped? Are door frames caulked?			
4. Are ceilings and walls insulated to the highest level recommended for your geographic location?			
5. Does the home have a vapor barrier in the walls to prevent water vapor from passing through and condensing into the insulation?			
6. Are floors insulated over unheated basements, crawl spaces, and garages?			
7. Do basement walls contain 2"x2" furring with R-7 insulation?			
8. Have you considered 6" walls with studs on 24" centers to allow maximum space for insulation?			
9. Has a clock thermostat been installed to reduce, automatically, evening temperatures?			
10. In colder climates, is window space on the north side of the house at a minimum?			
11. Is the home efficiently shaped to limit heat loss, avoiding L-, T-, and H-shaped configurations?			
12. Does the house have an overhang for the south wall which will protect it from summer sun, but allow exposure to winter sun?			
13. Does the fireplace have a heat exchanger to collect unused heat?			
14. Is the fireplace a high-efficiency type with a tight damper?			
15. Is fluorescent rather than incandescent lighting used in the kitchen and bathroom?			
16. Are outdoor gas lamps essential for safety or merely decorative?			
17. Does the landscaping shade the house in summer and let in winter sun?			

UNIT REFERENCES

The following publications are available from the:
Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509

1. Energy - Saving Checklist for Home Builders, Buyers, and Owners
2. Nebraska Energy Saving Manual
3. Heating with Wood
4. Residential Energy Conservation - A Money Saving Handbook for Nebraska

UNIT II

CONSTRUCTION TECHNIQUES FOR ENERGY EFFICIENT BUILDINGS

RATIONALE

The purpose of this unit is to provide the student with information concerning techniques in planning and constructing an energy efficient building, taking advantage of local topography, climate considerations, and complying with standard construction practices and state/local building codes.

ADVANCED PREPARATION

It is recommended that the publications, "Planning an Energy Efficient Home," "Residential Procedures Manual," and "Manual of Acceptable Practices," be obtained from the Nebraska Energy Office prior to beginning this Unit.

ANTICIPATED INSTRUCTIONAL TIME

The information contained in this Unit should be incorporated within an existing curriculum in Building Construction Technology.

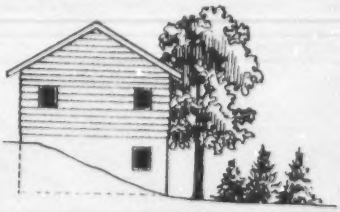
UNIT GUIDE

1. SITE SELECTION

   A. Consider a southern exposure for maximum solar heat gain in the winter months.

   B. Topography
      1. Build into a hillside
      2. Build partially into the ground

   C. Earth-berming
      1. Problems to overcome
         a. Loss of natural ventilation
         b. Waterproofing
         c. Drainage



House built into south slope hill.

2. WIND PROTECTION

   A. Shield buildings from northwest winter winds. This results in a reduction of wind velocity and subsequent heat loss.
      1 This is an important consideration in open rural or hilltop locations.

   B. Types of windbreaks
      1. Coniferous trees
      2. Out-buildings
      3. Fences
      4. Neighboring homes

3. SHADE

Area shaded varies with tree shape.

A. Deciduous trees
   1. Provide shade during summer months
   2. Allow solar heat gain in the winter months

B. Location
   1. Deciduous trees should be planted on the South and East to provide shading for windows, roof, and wall areas.

4. ORIENTATION

A. The main axis of the structure should be oriented EAST to WEST.
   1. Large glass areas are placed on the SOUTH
      a. Provides maximum solar gain in winter
   2. Small glass areas are placed on the NORTH
      a. Heat loss is reduced
      b. Infiltration is decreased
   3. Minimum western exposure
      a. Reduces summer afternoon heat gain

B. Locate unheated areas of the building to the NORTH and WEST to serve as a buffer from cold winter winds.

5. DESIGN

A. Analysis
   1. Complete an in-depth preliminary analysis to determine the present and future needs (uses) of the building.
      a. Size the building according to the results of the study.
      b. Overbuilding results in energy waste!

B. Shape
   1. Minimize the wall and roof areas, use the space efficiently.
   2. A SQUARE or multi-story building is more efficient than a rectangular, L-shaped, or spread-out design.

C. Floor Plan
   1. An open design is desirable for rooms receiving frequent use. This allows good heat distribution and circulation.
      a. Family room
      b. Kitchen
      c. Dining room
   2. Locate infrequently used rooms to the NORTH side of the structure. This provides a buffer against winter winds and allows for "zoning-off" when not being used.
      a. Bedrooms
      b. Bathroom
   3. Locate rooms that generate heat to the NORTH and EAST.
      a. Kitchens
      b. Laundry

FIGURE TWO

Suggested location for the different areas in a house.

Space	Suggested Location			
	N	S	E	W
Bedroom	X		X	
Family/Living		X	X	
Kitchen	X		X	
Play Space		X	X	X
Work/Hobby	X	X	X	X
Storage/Garage	X			X
Bathroom	X			
Laundry	X			
Eating/Dining		X	X	

D. Entrances

Entryways are potential areas for significant energy loss. A sound and thoughtful construction design can, however, reduce this loss. Methods to minimize direct air-flow heat loss include the construction of:

1. A vestibule
2. An alternate entry through a garage
3. An outside protective wall
4. An enclosed porch
5. A fence/windbreak

E. Window construction

Windows can add to the efficiency of a building (if well planned).

1. Total window area should be designed in relation to the total floor area.
2. Window construction should be planned for all sides of the building to take advantage of natural ventilation.
   a. Concentrate window area on the South to maximize winter solar heat gain.
   b. Minimize the window area on the North to prevent excessive heat loss.
3. Large window areas should be shaded during the summer to minimize excessive solar gain.
   a. Properly constructed overhangs - allow winter solar gain and block summer solar gain.
   b. Awnings
   c. Deciduous trees

F. Nebraska Building Energy Conservation Standards
   1. Three methods for demonstrating compliance
      a. Manual of Acceptable Practices (applicable only to 1-2 family dwellings).
      b. Residential Procedures Manual (Sections 4-8).
      c. Residential Procedures Manual (Sections 10-11).

   2. Copy of the Nebraska Building Energy Conservation Standards - Residential Building Certification Form. (See Inset)

UNIT ACTIVITIES

1. Arrange a student tour of residential structures that exemplify energy efficient versus energy inefficient construction practices.

2. Modify existing floor plans to accommodate energy conserving construction techniques.

3. Construct a site plan to accommodate energy efficient building orientation. Correlate the orientation to take advantage of climate, topography, and landscaping by planning for proper summer shading and winter windbreaks.

UNIT REFERENCES

The following publications are available from the:
Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509

1. Planning an Energy Efficient Home
2. Nebraska Building Energy Conservation Manual (Residential Procedures Manual)
3. Nebraska Building Energy Conservation Manual (Manual of Acceptable Practices)

NEBRASKA BUILDING ENERGY CONSERVATION STANDARDS

RESIDENTIAL BUILDING CERTIFICATION FORM

Building description: _____

Address _____

City/County _____

Climate zone (circle): A B C D E F

Building type (circle): one/two family multi-family, _____ units

Compliance path: _____ Manual of Acceptable Practice
_____ component performance (sections 4-8)
_____ building performance (sections 10 & 11)

Electric utility serving building site: _____

Property owner: _____

address: _____

_____

Architect/Engineer: _____
(if applicable)
address: _____

_____

Has approved/sealed building plans? _____ Yes _____ No

Prime Contractor: _____

address: _____

_____

"I hereby certify to the State of Nebraska, that I will construct the above named building, or portion thereof for which I have responsibility: (1) in compliance with all applicable portions of the Nebraska Building Energy Conservation Standard (current edition), or (2) according to the building plans to which the above named architect or engineer has affixed his or her state registration seal."

_____
Signature of prime contractor Date

Nebraska Energy Office • P.O. Box 95085 • Lincoln, Nebraska 68509

WHITE SHEET -- Nebraska Energy Office YELLOW SHEET -- Electric Utility PINK SHEET -- Contractor

UNIT III

INSULATION MATERIALS AND R-VALUES

RATIONALE

This Unit is designed to provide information concerning the effectiveness of insulation relative to its resistance to heat flow (R-value), composition, and thickness. This will also include a discussion of technical data, definitions, economics, calculations, and installation methods for various insulating materials.

ADVANCED PREPARATION

It is recommended that the following publications be obtained and used as guidelines for the study of this Unit:

- Insulation Manual by NAHB Research Foundation Inc.
- Providing for Energy Efficiency in Homes and Small Buildings by the Office of Consumer Affairs, Education Division, Washington, D.C. 20585
- Nebraska Energy Saving Manual, Nebraska Energy Office. Box 95085, Lincoln, NE 68509 ($.50 per book)

ANTICIPATED INSTRUCTIONAL TIME

The information contained in this Unit should be incorporated within an existing curriculum in Building Construction Technology.

UNIT GUIDE

1. TECHNICAL DATA

To effectively evaluate insulating materials and facilitate student understanding, the following items should be included in your instruction:

A. Definitions and terms

B. R-values of:
   1. Structural and finishing materials
   2. Air spaces
   3. Air films
   4. Insulating materials

C. ASHRAE Standard 90-75

D. Weather data and correction factors
   1. Average heating degree days data
   2. Current heating degree days data

E. Calculate heating loads (Winter Heat Loss)

F. Calculate cooling loads (Summer heat Gain)

G. Perform a building energy audit.

H. Calculate the cost/benefit ratio and payback period

2. INSULATION TYPES

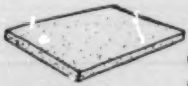
A. Flexible (blankets or batts)
   1. Composed of:
      a. Glass fiber
      b. Rock wool
      c. Balsa wood
   2. Used for 16" and 24" framing centers
   3. Used with or without vapor barriers
   4. Fire resistant, moisture resistant
   5. R-values

Where they're used to insulate:
unfinished attic floor
unfinished attic rafters
underside of floors

B. Loose fill (poured or blown in)
   1. Composed of:
      a. Glass fiber
      b. Rock wool
      c. Cellulose fiber
   2. Ideal for non-standard framing
   3. No vapor barriers required
   4. Fire resistant, moisture resistant
   5. R-values

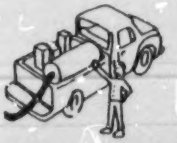
Where it's used to insulate:
unfinished attic floor

C. Rigid board (bead board, fiber board)
   1. Composed of:
      a. Pressed wood chips/fiber
      b. Styrofoam
   2. Used for 24" and 48" widths
   3. No vapor barriers required
   4. No fire protection required
   5. R-values



Where it's used to insulate:
basement wall

D. Foamed in place (ureaformaldehyde)
   1. More expensive than other insulation materials
   2. Fire resistant, moisture resistant
   3. Illegal to use in some states
   4. R-values



3. STRUCTURAL AREAS TO INSULATE

For each structural area listed below, be sure to determine the most appropriate insulation type and the highest cost/benefit R-value. REMEMBER - always reference the most stringent building code affecting your locality!

A. Slab floor perimeters

B. Foundation top

C. Finisned or heated basement walls

D. Floors and crawl spaces

E. Exterior walls

F. Ceilings

G. Finished attic and knee walls

H. Duct work

I. Other areas
   1. Scuttle holes
   2. Built-up headers
   3. Corner posts
   4. Door framing

4. APPLICATION

NOTE: Always wear gloves, safety glasses, and heavy clothing when working with fiberglass and rock wool to protect eyes, hands, and other body parts. All installation of insulation should be coordinated with other contracted trades. Appropriate tools are required for cutting and fitting most insulation.

A. Side walls
   1. Blow-in cellulose fiber
   2. Foam-in ureaformaldehyde
   3. Friction-fit batts (heavy-duty shears or utility knife)
   4. Staple-in blankets (heavy-duty shears or utility knife)
   5. Nail-on sheathing (hand saw)

B. Ceilings
   1. Blow-in rock wool, fiberglass, or cellulose
   2. Friction-fit batts of fiberglass or rock wool (utility knife)
   3. Staple-in blankets of fiberglass or rock wool (utility knife)
   4. Provide ventilation through rafters to soffit

C. Crawl spaces
   1. Install blankets or rigid board insulation
   2. Vapor barrier and proper ventilation are required
      installation procedures for the band joist, foundation wall, and perimeter (floor joists are optional)

D. Floors
   1. Friction-fit batts or blankets of fiberglass or rock wool, support with chicken wire
   2. Vapor barrier is required (placed up or toward the warm side)

E. Basement walls
   1. Friction-fit batts or blankets of fiberglass or rock wool.
   2. Cut and fit rigid board insulation of fiberboard or styrofoam.
   3. Vapor barrier is required (placed in or toward the warm side)

UNIT ACTIVITIES

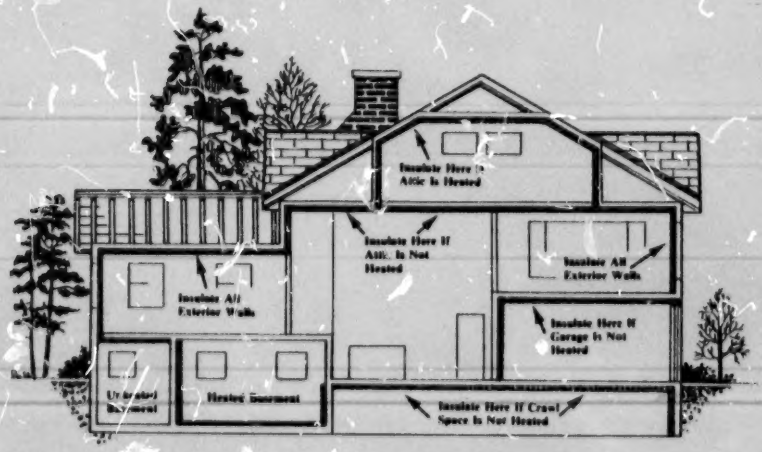
1. Have students, with your assistance, perform a thorough energy audit of the school facility. Upon completion, assign students to perform an energy audit of their home or local community building.

2. Have students, individually or in groups, research various insulation types and report their findings relative to major advantages, disadvantages, R-values, suggested areas of use, vapor barrier requirements, tools required for installation, and proper safety precautions.

3. Have students construct a plan to coordinate the installation of insulation with other construction trades.

UNIT REFERENCES

1. Insulation Manual, 2nd edition, by NAHB Research Foundation, Inc., 627 Southlawn Lane, P.O. Box 1627, Rockville, Maryland 20850
2. Residential Energy Conservation from the Nebraska State Energy Office, Box 95085, Lincoln, Nebraska 68509
3. Providing for Energy Efficiency in Homes and Small Buildings from the Office of Consumer Affairs, Education Division, Washington, D.C. 20585
4. All Weather Home Building Manual, NAHB Research Foundation, Inc., 627 Southlawn Lane, P.O. Box 1627, Rockville, Maryland 20850
5. Energy Conservation in New Building Design,(Standard 90-75). ASHRAE
6. All Weather Wood Foundation System vs. Conventional Poured Concrete, American Plywood Association


Insulate Here If Attic Is Heated
Insulate Here If Attic Is Not Heated
Insulate All Exterior Walls
Insulate All Exterior Walls
Insulate Here If Garage Is Not Heated
Unheated Basement
Heated Basement
Insulate Here If Crawl Space Is Not Heated

UNIT IV

CONSTRUCTION MATERIALS AND APPLICATION

RATIONALE

This Unit is designed to provide the student with information concerning various ways to conserve energy with regard to the selection and application of building materials. This will include a discussion of window, door, and framing materials to improve the efficiency of energy use in new residential structures.

ADVANCED PREPARATION

It is recommended that the following publications be obtained from the Nebraska Energy Office prior to beginning this Unit:

- Nebraska Energy Saving Manual
- Residential Energy Conservation - A Money Saving Handbook for Nebraskans
- Energy Conservation with Windows

(NOTE: Any Building Construction text should adequately cover framing, window, and exterior door installation.)

ANTICIPATED INSTRUCTIONAL TIME

The information contained in this Unit should be incorporated within an existing curriculum in Building Construction Technology.

UNIT GUIDE

1. SELECTING BUILDING MATERIALS

Several factors require consideration when selecting appropriate materials to build a structure which will not only be energy-efficient, but also durable and attractive.

Each construction material has its advantages and disadvantages. Some are good for only one specific use while others serve several functions. Material requirements also vary with interior or exterior use.

The choice of materials to construct an energy-efficient building should be based on effectiveness against weather, degree of insulation, durability of the surface (both inside and out), local availability, ease of construction (based on skill of labor available), attractiveness, and cost.

In all buildings, a combination of materials will be needed to do the job. TASK ONE will help you select building materials.

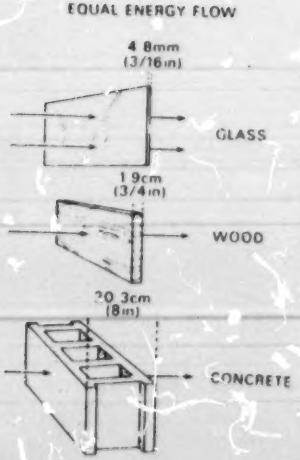
TABLE ONE

ENERGY-SAVING CHARACTERISTICS OF BUILDING MATERIALS

Construction Material	Insulation Capacity	Infiltration Resistance	Heat Storage Capacity
Aluminum	Low	High	Low
Asphalt shingles	Low	High	Low
Brick	Low	High	High
Concrete	Low	High	High
Earth	Medium	High	High
Glass	Low	High	Low
Gypsum Board	Medium	High	Low
Insulation	High	Medium	Low
Steel	Low	High	Low
Stone	Low	High	High
Wood	Medium	Medium	Low

NOTE: Some building materials are more resistant to heat flow than others. For example, just as much heat will be lost through an eight inch concrete block wall as through a 3/4 inch wood wall. Even more heat will be lost through a single pane window. (FIGURE THREE). You, as a builder, should consider using combinations that will allow the least heat transfer.

FIGURE THREE



H. Standard 3 1/2 inch stud wall

A typical building construction methodology involves the use of standard 3 1/2 inch (2x4) stud walls. These stud walls have an R-value approximately equal to 4.0. An R-value of close to 20.0, however, is a desirable energy efficient target. To achieve this, the air space between the studs must be insulated by replacing the 3 1/2 inches of dead air space (R-value = 1.0) with 3 1/2 inches of insulation (See TABLE TWO).

TABLE TWO

INSULATION TYPES (3 1/2 Inches)

3 1/2 Inches	R-Value
Vermiculite or Perlite	11.9
Fiber Glass	13.7
Mineral Wool	13.7
Cellulose Fiber	15.4
Polystyrene (White)	17.2
Ureaformaldehyde	17.7
Polyurethane	25.5

Most of these insulations, installed at 3 1/2 inches, will not bring the wall up to the desired R-value. The addition of polystyrene or urethane sheets directly to the studs prior to sheetrocking will increase the R-value to approximately R=19.0.

B. 5 1/2 inch stud wall

A good alternative method of wall construction involves the use of 5 1/2 inch stud walls (2x6). These stud walls leave more space for the use of insulating materials. By using this construction, R-values are increased resulting in a more energy efficient structure. (See Table Three).

TABLE THREE

INSULATION TYPES (5 1/2 Inches)

5 1/2 Inches	R-Value
Vermiculite or Perlite	16.9
Fiber Glass	19.7
Mineral Wool	19.7
Cellulose Fiber	22.4
Polystyrene (White)	25.2
Ureaformaldehyde	27.7
Polyurethane	38.9

The use of 2x6 studs (24 inches on center) rather than 2x4 studs (16 inches on center) will slightly increase construction costs. The increased costs, however, can be justified by the energy and monetary savings resulting from increased insulation capacity. (2x6 construction also allows for a choice of insulation based on cost rather than R-value since 5 1/2 inches of most insulations is 19.7 or better.)

2. WINDOWS

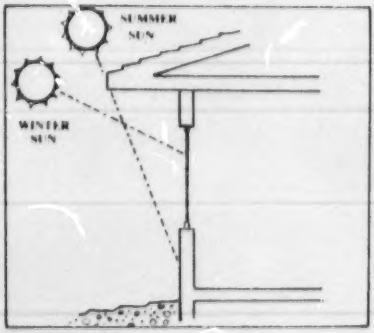
Since glass is a poor type of insulation, the more windows you have, the more heat loss you can expect. Therefore, it is often assumed that a house with a large amount of window area must use more energy than one with less. While this is frequently true, it is also true, however, that a house with windows that are well-designed, well-located, and properly used can actually save money!

In the winter, the south side of a house receives the most intense sunlight. In summer, the sun's rays are most intense on the southeast and southwest. To gain needed heat in the winter, the south side should have the largest window area.

To avoid excessive heat gain in the summer, southern windows should be shaded by a roof overhang or other means of exterior shading. The key is to stop the sun before it enters the house through the windows. It is many times more effective to stop the sun with an exterior protection or shade than with interior draperies, shades, or window film.

Due to change in the sun's angle from winter to summer, a properly constructed overhang shades the window in summer, yet allows the winter sun's warmth to enter the home. In Nebraska, a general rule of thumb for a typical one-story house is that a southern overhang should be a minimum of 30 inches wide. (If the overhang of the roof is insufficient, an awning or operable shutter can shade the windows.)

FIGURE FOUR



Northern windows should be kept to a minimum in size and number. They receive no direct sunlight and are a specific source of heat loss.

Windows should be planned to take advantage of natural ventilation, which can help reduce the need for summer cooling. Windows on opposite sides of the house will allow cross-ventilation. It is generally best to have some window area on all sides of the house, to take advantage of natural breezes.

In many energy efficient research homes, the total glass area has been reduced to eight or ten percent of the home's total square footage. This dramatically reduces heat loss and air infiltration through and around windows.

Reducing the window area can also reduce the amount of natural light available. Therefore, well-planned, energy efficient lighting will be needed. Generally, the energy cost for additional artificial lighting is more than offset by the energy savings from reduced heat loss though the windows.

FIGURE FIVE

FORT MYERS, FLORIDA HOME built by Ryce Stallings and J. Roger Brown Jr. features passive solar cooling.

To summarize, windows can add to the efficiency of a house if well planned. The total window area should be in relation to the total floor area. There should be some window area on all sides of the house for ventilation, but the greatest window area should be on the south side, for winter heat gain. Summer shading of windows is needed, and energy-efficient styles should be used.

FIGURE SIX

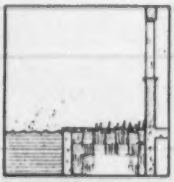
1 KEEP COLD TEMPERATURES OUT Insulate your home from the winter cold by building compact floor plans, insulating walls, and carefully using window areas to minimize heat loss. Also allow the living space to be open to comfortable conditions.

2 LET THE SUN IN On winter days, let the sunlight in for daytime warmth and passive nighttime heating.

3 ALLOW WINDS TO VENTILATE Design for maximum ventilation when it's an asset when it's too hot for comfort.

4 AVOID INFILTRATION

5 KEEP THE SUNLIGHT OUT Sunshine is a liability when it's too hot for comfort and can result in excessive dependence upon mechanical air conditioning.



6 AVOID CREATING HUMIDITY Additional humidity could cause discomfort and overheating.

A. Installation - Good workmanship is essential. Attention to detail in framing and trimming around windows can reduce air infiltration problems.

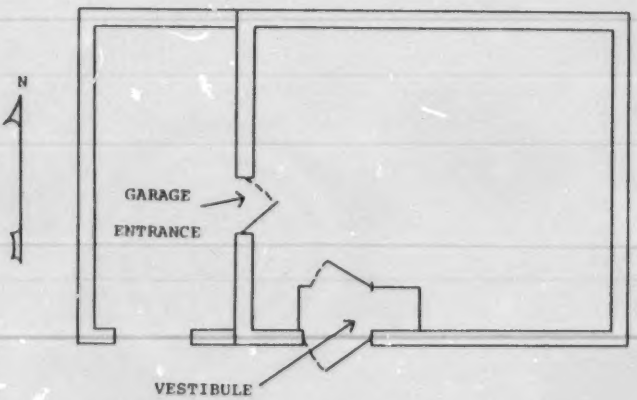
B. Insulation - When installing windows, the area between the window unit and the rough opening should be insulated.
   1. Fiberglass or rock wool are the most appropriate insulations.
   2. Insulation should fill the gap without being too tightly packed.
   3. A vapor barrier should also be installed, covering the insulation on the inner or warm side of the window.

C. Caulking - Should be used in the following gaps:
   1. Between window drip caps and siding
   2. At the joint between frame and siding
   3. Between sill and siding
   4. Where storm windows meet frames (except for drain holes at the window sill)

3. DOORS

Entrances are potential areas for significant energy losses. When exterior doors open directly into the interior of the house, large amounts of heated or cooled air may escape each time they are opened. Buffer areas around main entries are effective in minimizing this air flow. A vestibule or garage entrance serves this purpose.

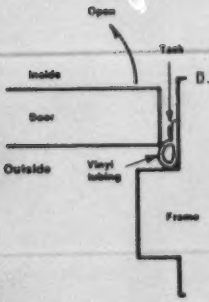
FIGURE SEVEN



A. Door Types
   1. Polyurethane insulated metal doors - with magnetic weatherstripping and a storm door, the most energy efficient choice of exterior door.
   2. Solid core wood doors - less energy efficient than (1), but have the aesthetic value of wood. (Some carpenters prefer to install wood doors because they may be built and trimmed to fit existing jambs.)
   3. Polystyrene insulated metal doors - less energy efficient than (2).
   4. Uninsulated metal doors - less energy efficient than (3).
   5. Tight fitting storm doors - recommended for every door type (1-4). Storm doors create a dead air space that reduces infiltration and increases insulating R-values.

B. Caulking - should be applied (to reduce infiltration) in the following areas:
   1. Between door drip caps and siding
   2. At the joint between frame and siding

C. Weatherstripping - no door installation is complete until weatherstripping is applied. There are many satisfactory types available. Install appropriate weatherstripping according to manufacturer's specifications.



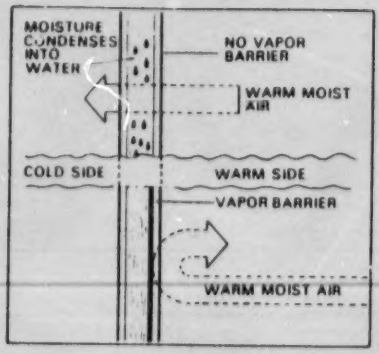
D. Door gaps - infiltration underneath exterior doors can be a major source of energy loss. Follow manufacturer's recommendations to install one of the following:
   1. Sweeps - useful for flat thresholds, (but may drag on carpets). Some models "flip-up" when doors are opened to eliminate dragging.
   2. Shoes - useful for installation on wooden doors over wood thresholds. Some metal doors come with door shoes.
   3. Vinyl bulb - available in either metal or wood types. Replacement bulbs are also available.
   4. Interlocking thresholds - more difficult to install but they provide an exceptional weather seal.

4. VAPOR BARRIER TYPES

Vapor Barriers are an essential part of the energy efficient building. Insulation in a wall, ceiling, or floor must be protected by a vapor barrier, applied to the warm side of the insulation. Without it, moisture from the house air will enter the insulation, condense and cause serious problems. When moisture works its way into insulation, the insulation becomes a conductor of heat and loses much of its R-value.

A vapor barrier is simply a layer of nonporous material on the inside surface of the insulating material. Should moisture collect on the vapor barrier, it cannot pass through to the insulation and it eventually evaporates into the room. Thus, the insulation in the wall remains dry and effective.

FIGURE EIGHT



A. Polyethylene film

When polyethylene film is used, it is laid or stapled on the warm side of the studs, ceiling joists, or rafters. It is available in thicknesses of 2-6 mil and widths of 3-20 feet. (Four mil or thicker is generally used for vapor barrier purposes.)

NOTE: When Polyethylene is used as a vapor barrier, it eliminates the option of using adhesive materials in the installation of drywall.

B. Aluminum foil and Nonporous paper

Aluminum foil and nonporous paper barriers, usually part of insulation rolls or boards, are placed so that they are toward the warm, interior living space. Joints should be taped with aluminized tape to make a tighter air and vapor seal.

In the case of foil-backed gypsum board, the foil side is placed against the wall studs or ceiling joists which are insulated with non-vapor barrier material. As with all phases of construction, good workmanship is important. Extreme care should be exercised in the installation of vapor barriers and any damage done during the installation should be repaired.

While vapor barriers must be cut to fit around doors, windows, and electrical outlets, the openings should be no larger than necessary. All outlets should be located and cut around prior to installation of drywall as a precaution against covering boxes during the installation of drywall. The effectiveness of any vapor barrier may be greatly reduced by improper installation or damage to the vapor barrier during installation.

C. Paints and other water resistant finishes

Various paints and other water resistant finishes may be used on interior room surfaces as a moisture barrier when other methods are not feasible. When remodeling older buildings, where interior walls and ceilings are not being replaced, this may be the only alternative. Aluminum paint, rubber based paints, varnish, and some urethane finishes serve this purpose.

UNIT ACTIVITIES

1. Have students design a wall construction using standard 3 1/2 inch wall studs to include the following:
   A. Insulation material
   B. Vapor barriers
   C. Construction timetable

2. Design a wall construction using 5 1/2 inch wall studs to include the same items as in (1).

UNIT REFERENCES

The following publications are available from the:
Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509

1. The Nebraska Energy Saving Manual ($.50 per book)
2. Residential Energy Conservation Manual
3. Planning an Energy Efficient Home
4. Providing for Energy Efficient Homes and Solar Buildings

UNIT V

ACTIVE AND PASSIVE SOLAR SYSTEMS

RATIONALE

The increasing cost of all conventional energy sources has promoted the rapid development of several alternative building construction methods to incorporate the utilization of active and passive solar technology. It is the responsibility of builders and other tradesmen to understand and implement appropriate solar technology. This unit is designed to explore various aspects of both active and passive solar energy technology.

ADVANCED PREPARATION

It is recommended that the publications "Nebraska Passive Solar Primer", "Nebraska Energy Saving Manual", and "Solar Factsheets" be obtained from the Nebraska Energy Office prior to beginning this Unit.

ANTICIPATED INSTRUCTIONAL TIME

The information contained in this Unit should be incorporated within an existing curriculum in Building Construction Technology.

UNIT GUIDE

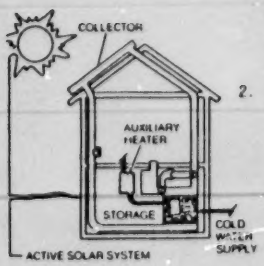
1. ACTIVE SOLAR SYSTEMS

An active solar system is one that involves the use of sophisticated mechanically operated equipment. It is used to collect, store, and distribute solar energy. Installation of active solar systems, on new buildings or as retrofits on existing structures, should only be considered when the life cycle cost or payback occurs within a reasonable time period. Installation of these systems requires concerted appraisal, planning, and sound judgement.

A. Collector Types

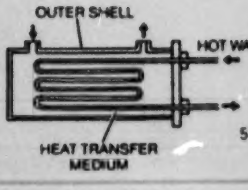
1. Concentrating
   a. Curved surface
   b. Parabolic shape
   c. Water or liquid-filled
   d. Generates high temperatures

2. Flat Plate - Enclosed box with an absorber plate
   a. Covered with glass or plastic
   b. Fixed position/Forced air operation
   c. Inexpensive to build/Painted metal or wood
   d. No air or water passage is necessary
   e. Withstands high temperatures



3. Solar Test Modules - A series of sheet metal boxes with a fan operated exhaust sytem
   a. Black, cloth-covered, insulated surface
   b. Air enters the lower left and circulates through chambers to the upper left
   c. Proven to be better than 50 percent effective
   d. Inexpensive to build
   e. Minimal maintenance
   f. Can be added to a hip, valley, or gambrel roof
   g. Air can be pumped out of the building to be recirculated through the module collectors.

4. Solar Hot Water Heating - a series of roof collectors for the purpose of heating water for domestic use
   a. Commercially produced
   b. Water is heated as it passes through the collector and pumped into a storage tank.
   c. Number and mass determined by building size
   d. After sunset, a thermosiphon is used to remove water from the collectors. This avoids freezing.



5. Wind Generators - solar temperature gradients produce prevailing winds
   a. Where they can operate
   b. Generation capacity
   c. Cost effectiveness
   d. Constant wind velocity

2. PASSIVE SOLAR SYSTEMS

A passive solar design is one that optimizes the natural heating capacity of the sun. Passive designs require little hardware, minimal maintenance, and no mechanically operated equipment. Passive design requires converted planning, landscaping, and a back-up heating system.

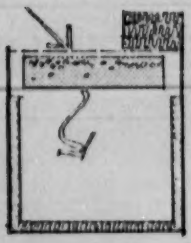
A. Placement, Setting, and Orientation
   1. Choose a southern exposure, hillside, or other area well suited for solar construction.
   2. Align the major axis of the structure East-West, with a south-facing front.
   3. Plan the structure's interior to maximize solar heat gain
      a. Living, dining, and kitchen areas should be placed on the South and East.
      b. Bed, bath, storage, and garage areas should be placed on the North and West.
   4. Plant deciduous trees on the South
      a. Provide summer shade
      b. Allow winter heat gain
   5. Plant coniferous trees on the North to block winter wind.

B. Roof Overhang
   1. Blocks summer sun to prevent solar heat gain (Summer sun angle = 75.5 degrees on June 21, 43 degrees latitude).
   2. Allows solar heat gain from winter sun (Winter sun angle = 30.0 degrees on January 21, 40 degrees latitude).

C. Berm Wall - Earth sheltering on the north side of the structure.
   1. Blocks the North winds
   2. Provides insulation in the winter
   3. Provides cooling capacity in the summer

D. Direct Gain - Thermal storage mass
   1. Dark painted masonry, brick or concrete walls absorb daylight solar radiation, store it, and re-radiate the heat at night.
   2. Tile, brick, or concrete flooring
   3. Water-filled columns or drums have 5 times the heat storage capacity of masonry.
   4. Movable insulation is placed over the glazing at night to prevent heat loss.

E. Indirect Gain - Trombe walls
   1. Thermal storage mass is placed next to and inside the glazed (window) area
   2. Thermal mass performs the same function as in D-1 but also sets up a natural convection current during daylight hours.
   3. Movable insulation is placed over the glazing at night to prevent heat loss.



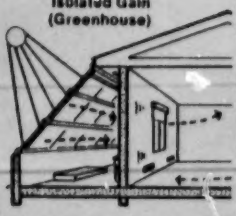
F. Thermal Roof Storage
   1. Roof ponds use water to store solar energy.
   2. The roof itself is made of steel to conduct heat
   3. Specially designed plastic bags, resembling water beds, are placed on a flat roof and filled with treated water.
      a. Heating season - roof ponds open during the day, covered at night
      b. Cooling season- covered during the day, open at night.

G. Greenhouses

Greenhouses are a relatively inexpensive way to add space to older buildings, or incorporate it into new ones. The properly designed greenhouse will add heat to the building and provide an opportunity to supplement the food supply of the occupants.

Ideally, greenhouses should face south for maximum exposure to the sun. Windows or vents at the upper and lower parts of the building wall allow entry and circulation of fresh, warm air which collects in the highest parts of the greenhouse. Ventilation to the outside and shading overhangs should be provided to prevent the greenhouse from becoming overheated in the summer or when heat is not required in the building.

Isolated Gain (Greenhouse)

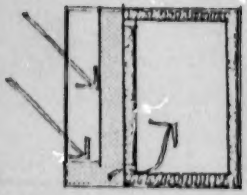


The most common glazing materials for greenhouses are glass, fiberglass or plastic. Insulation of the glazing plus thermal mass in the form of water-filled containers, masonry support structures, rock or slab floors, or a combination of all these elements, must be used inside the greenhouse. In temperate climates a single layer of glazing is all that's necessary. In more severe climates, double glazing and insulation may be necessary during sunless periods. Thermal mass and insulation of the glazing help control the wide fluctuations in temperature which may otherwise occur.

A solar greenhouse can create an attractive border between the living space and the outdoors. It also established a thermal "buffer zone" which can substantially reduce heat losses. An attached greenhouse makes an attractive vestibule entrance to the house, and one which can reduce the infiltration of cold winter air into the building.

H. Isolated Gain

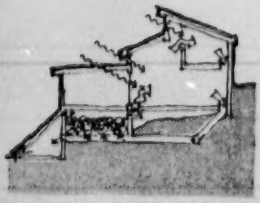
1. Sunspace



The sunspace, isolated gain, passive building type collects solar radiation in a secondary space, separate from the living space, and stores heat for later distribution. This "sunspace" offers both the potential separation of the collector-storage system from the living space or the direct-gain "live-in" situation which maximizes the use of low temperature solar gain. Thus, in concept, a "sunspace" passive solar system is midway between a Direct Gain and Indirect Gain system.

a. An atrium
b. Sun porch
c. Sunroom

2. Thermosiphon



A thermosiphoning heat flow occurs when cool air or liquid naturally falls to the lowest point (in this case below the collectors) and once heated by the sun, rises up into an appropriately placed living space or storage mass, causing somewhat cooler air or liquid to fall again, so that a continuous heat gathering circulation is begun. Since the collector space is completely separate from the building, the Thermosiphon system resembles the active systems. No external power from fans or blowers is needed to move the heat transfer medium. The Thermosiphon principle has been applied in numerous domestic solar hot water systems, and offers equally great potential for space heating application.

a. Components
    1. collector space
    2. storage mass
    3. method of distribution
b. Collection surface
    1. Dark metal
    2. Wood

The collector space is not fixed by the building and thus can take maximum advantage of sun exposure.

UNIT ACTIVITIES

1. Arrange a tour to a site using an active solar system and another to a passive solar home.

2. Have students design plans for the construction of a home to incorporate one of the following solar technologies:
   A. Concentrating collectors
   B. Flat plate collectors
   C. Solar test modules
   D. Hot water heating system
   E. Direct gain
   F. Trombe walls - Indirect gain
   G. Thermal roof ponds
   H. Greenhouses
   I. Isolated gain

UNIT REFERENCES

The following publications are available from the:
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1. Nebraska Energy Saving Manual ($.50 per book)
2. Nebraska Passive Solar Primer
3. Solar Factsheets

Other References

1. Fundamentals of Solar Heating, Prentice Hall Publishing, United States Department of Urban Development, Washington, D.C.
2 Inside Education, Energy Issue, Nebraska State Education Association